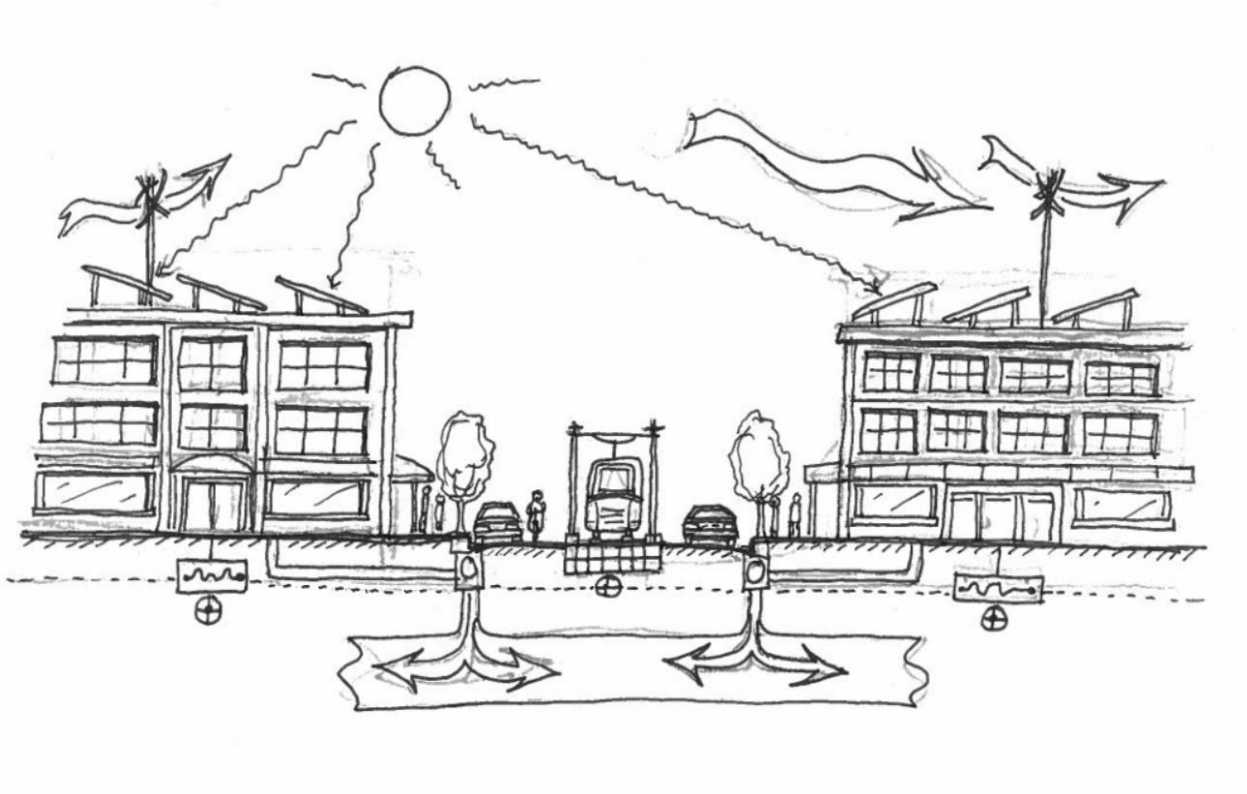
# *ATTRACTIVE EFFICIENCY*:
## THE EMERGING ENERGY CRISIS &
## STRATEGIES FOR ENERGY EFFICIENT URBAN DESIGN



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# ABSTRACT

**BACKGROUND**

American patterns of urban development are generally characterized by sprawl, automobile-centric transportation networks, and free market abundance. America's post-WWII urban expansion and infrastructure emplacement was built when the United States was the world's leading producer of hydrocarbon energy, and therefore did not make transmission efficiency a priority. The energy picture today is much different as world population grows, and demand for limited fossil fuels continues to rise.

This nation needs a new scheme of urban development awareness that combines contemporary urbanism planning paradigms with the latest energy distribution network. Together, these two components address the way we utilize energy, and rethink the efficiency of our urban system in an effort to quantitatively reduce per capita energy consumption. Together, these components—smart growth combined with the smart grid—formulate *attractive efficiency*: an integrated, strategic approach of employing smart grid technologies with desirable design techniques from the human perspective in order to enable people to become conscious consumers within their community.

**OBJECTIVE**

The objective of this paper is to create a qualitative examination of the factors that can lead to a more sustainable path for the urban environment. The impending energy crisis review serves as the context for action. Additionally, many lessons can be learned by studying energy efficiency initiatives in Boston, Austin, and Atlanta, and can form an understanding of the "starting point" of American urbanism. Finally, through an explanation of attractive efficiency as a new mean of providing energy efficient and desirable places to live, this paper will lay out strategies in order to address energy transmission and consumption, and to provide a framework for all cities to become more resilient places for the twenty-first century.

**DATA SOURCES**

Information pertaining to the context of energy consumption and availability is derived from the United States Energy Information Administration (EIA), the Department of Energy (DoE), Daniel Yergin's *The Quest*, and *The End of Oil* by Paul Roberts. Smart grid and case studies references come from current publications and journals including *Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities* by David Fox-Penner, the U.S. News and World Report, and the Energy Efficient Cities Initiative. Urban Design principles are derived from *Urban Design and People* by Michael Dobbins, *The Urban Design Handbook* by Urban Design Associates, and *Redesigning Cities* by Jonathan Barnett.

**CONCLUSION**

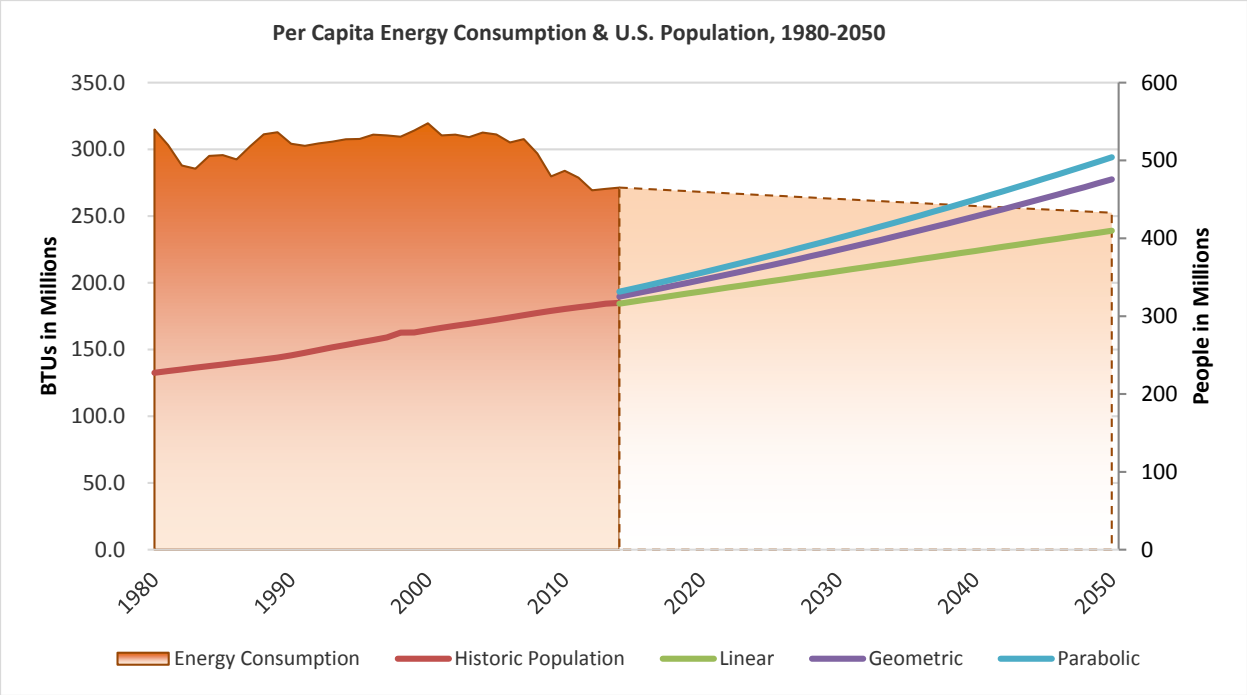
Increased urban efficiency can be attained through a combination of policy, regulation, and public outreach initiatives to decrease consumption. Additionally, energy efficiency goals can be attained within the context of good urban design where people can live, work, and play. Remaining on the status quo path of energy use is unsustainable and costly in the long term. Collectively, we can take action now to influence energy policy toward more independent and sustainable means, or wait until the crisis is upon us. It is our duty as stewards for future generations to forge the path toward a new, long-lasting America for all people.

**Introduction: American Urbanism on the Fringe**

America has been energized by the promise of boundless possibility since its inception. The principles of liberty and freedom in the nation's founding documents laid the foundation for this promise, while subsequent presidents have steadfastly pointed the nation toward the future with truisms of prosperity, enterprise, and individual advancement. As the democratic experiment unfolded across the continent, the advancement of society appeared to be both obvious and certain; the very foundation of the "manifest destiny" doctrine. This philosophy—unique among all the countries of the world—has come to define American Exceptionalism, and has guided public policy toward this limitless end. Millions have flocked to the nation's cities, armed with this promise, in order to stake out personal prosperity. With this massive influx over the past two hundred years, America's energy demands have grown ever more exorbitant.

Despite this urge to sprawl from sea to shining sea, the energy resources of our nation—and our world—are diminishing, and will eventually be extinguished altogether. According to the U.S. Census Bureau, the nation continues to grow at a rapid pace, from 317 million in 2014 to over 410 million by 2050, according to scenarios based on immigration, birth rate, and economic vibrancy[1]. With this growth comes the insatiable appetite for energy resources that sustains unfettered development. In 2013, annual per capita energy use in the United States is estimated at 271.4 million BTUs, for a total of about 215.5 billion BTUs of energy for the country. By 2050, annual per capital energy use is expected to decline slightly to 251.8 million BTUs, but as a nation our annual consumption of energy will soar to approximately 260.2 billion BTUs[2]. The cause of this decrease is due to factors such as projected technologic improvements in electronics, government implemented standards of fuel efficiency (i.e., Corporate Average Fuel Economy), and changing patterns in consumption.

[1] U.S. Census Bureau, Population Estimates and Projections, 1980-2050.
[2] U.S. Energy Information Administration, "Annual Energy Outlook, 2013 with Projections to 2040 [Extrapolated to 2050]." April 2013.




U.S. Census Bureau, U.S. Population Counts; U.S. Department of Energy, Short-Term Energy Outlook, March 2014

How does the United States compare with the rest of the world in terms of energy consumption? On a per square mile basis, Americans are one of the leading consumers of energy, ranking second to the United Arab Emirates. However, no other nation on the planet consumes more energy on a net total basis than the United States. According to the Global Footprint Network, if the 7 billion people in the world lived like Americans, then we would need 4.1 planet earths to sustain the same quality of life per person[3]. This is clearly an unsustainable trajectory that necessitates thoughtful discourse for the future of urban settlement.

Cities are fueled with enormous quantities of coal, petroleum, natural gas, nuclear, and—to a lesser degree—renewable energies. Even though per capita consumption is decreasing, the U.S. Energy Information Administration (EIA) projects that aggregate energy consumption will increase by 13% in

[3] Global Footprint Network: Advancing the Science of Sustainability. "National Footprint Accounts." http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_data_and_results. Last accessed 15 March 2014.

2035[4]. Hydrocarbon fuels will encompass approximately 80% of this amount, leaving the remaining one-fifth comprised of nuclear, hydroelectric, solar, geothermal, and other resources[5]. For this reason, it is the priority of the Department of Energy to invest in programs that will transition American dependence off of high carbon-emitting fuel sources and promote the proliferation of renewables[6]. One such example is outlined in the Energy Independence and Security Act (EISA) of 2007, which provides a goal for new buildings to reduce fossil fuel consumption relative to 2003 levels by 100% by 2050. The goals are in place, yet the means to achieve them are in perpetual dispute.

**America's Energy: A Finite Enterprise**

The impetus for transition to a society of smarter energy consumption is threefold. First, hydrocarbon fuels are a finite resource, and available resources are expected to decrease in the coming years. Scientists and policymakers have been debating the projected point at which oil availability decreases, creating the *peak oil theory*: the point where half of the original supply of oil has already been extracted from the ground and consumed. This theory originated with the works of M. King Hubbert, a geophysicist working for Shell Oil who published a report in 1956 on remaining reserves. This report analyzed trends and projected reserves of the oil industry in the United States to provide a summary for stakeholders and policymakers. Using mathematical modeling, Hubbert predicted that the United States would decline in oil production in 1969. Hubbert was almost correct: the nation began to decline oil output as predicted from the 1970 peak, but the trend has increased again since the mid-2000s with technological breakthroughs that tap into previously inaccessible reserves[7]. Likewise, on a worldwide scale, peak oil production has been pushed farther into the future as more oil fields are

[4] U.S. Energy Information Administration. "Analysis of Impacts of a Clean Energy Standard as requested by Chairman Bingaman." 30 November 2011.
[5] Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy. "Strategic Plans." http://energy.gov/eere/about-us/plans-implementation-and-results/plans-implementation-and-results-glossary#strategic_plans. Last accessed 23 November 2013.
[6] U.S. Department of Energy, Short-Term Energy Outlook (STEO), March 2014.
[7] Roberts, Paul. "The Last of the Easy Oil." *The End of Oil*. First Mariner Books, New York. 2004. Pp. 46-48.

discovered, new technologies emerge that allow access to more oil and gas, and political dynamics change either restricting or relenting to allow oil companies to access protected land and water.

It is difficult to say exactly how much energy is left in the world, largely because there are two types of energy sources: proven and undiscovered reserves. The undiscovered component of the remaining energy equation is based on geologic probability, technological capability, and geopolitical constraints. These figures can be inflated or deflated for political leverage, resulting in more uncertainty than concrete evidence. Furthermore, it is difficult to ethically rationalize which state, corporation, or society is entitled to these resources. The EIA estimates that oil producing nations collectively extract between 80 and 85 million barrels of oil out of the Earth in 2009, with oil-consuming countries expending about the same amount. Furthermore, the latest modeling estimates predict that the world will exhaust its reserves of oil in by 2060, coal by 2090, and natural gas by 2120[8]. This is alarming, as these outcomes extend only a few generations away. History is rife with man's persistent ambition to secure precious energy resources through trade agreements, diplomacy or warfare. A world of energy exhaustion would undoubtedly lead to unprecedented instability on virtually every front: populations in revolt, food shortages, inhospitable climates, and political turmoil.

Second, the environment is often a casualty of the oil, coal, and natural gas industries. Companies that produce these hydrocarbons are facing increased expenses to properly control the externalities of air pollution, water contamination, and irreversible ecological depredation. The cost of extracting hydrocarbon fuels is mounting as environmental protection becomes a prominent issue in energy policy. While the deficit of environmentally-sound practices of energy extraction increases, there is no shortage to the criticism of these practices on the biological and ecological systems on which the nation relies.

[8] U.S. Energy Information Administration. "EIA Energy Conference & Presentations," 7 April 2009.

America is undergoing an energy renaissance due to the natural gas boon in shale fields across the country, including the Bakken of North Dakota, the Marsellus of Pennsylvania and Ohio, and the Eagle Ford of Texas. In order to access natural gas beyond the ability of conventional means, oil companies are relying on hydraulic fracturing, or fracking, which is an energy-intensive process with considerable ecological costs. Fracking has been used since the 1940s, but it wasn't until the late 1990s when techniques using sand and trade-secret chemicals allowed oil companies to penetrate into deeper shale rock. By 2008, the industry was using fracking in conjunction with horizontal drilling techniques to access previously-unreachable reserves of oil and gas.

The environmental toll of fracking is substantial, and researchers are revealing new negative externalities. Fracking requires intense amounts of water to completely extract the fuel, ranging from 1 to 8 million gallons of water per job, combined with approximately 40,000 gallons of undisclosed chemicals[9]. After the job is complete, the toxic solution either remains in the earth or is pumped back up to the surface where it is treated in retention ponds. There is a high risk for indirect contamination of aquifers and drinking water sources, as researchers have proven that methane levels can be up to 17 times higher near fracking sites than normal water sources. Even more alarmingly, evidence is showing a strong correlation between intensifying fracking operations and increased frequency of earthquakes. As recently as April 7, 2014, Oklahoma has surpassed the annual record of earthquakes from previous years—in four months. The average annual number of tremors in Oklahoma from 1975 to 2008 has been 3, but has risen to 40 per year from 2009 to 2013. Preliminary data for 2014 indicates 252 earthquakes have occurred in near fracking sites[10]. Similar allegations against the oil industry have arisen in Ohio, Texas, and Kansas, and many activist groups are demanding increased regulation and

[9] Earthworks Action. "Hydraulic Fracturing 101: What it is." http://www.earthworksaction.org/issues/detail/hydraulic_fracturing_101#.U0VpqvldWSo. Last accessed 9 April 2014.

[10] Gillam, Carey. "Series of Small Earthquakes Rock Oklahoma in Record Seismic Activity." Reuters. 5 April 2014.

investigations into the fracking business. It may not be definitively clear that this increased seismic activity is directly related to fracking, but it is evident that much remains unknown about this rapidly emerging hydrocarbon extraction process.

Localized environmental degradation is also evident in the Canadian oil sands, where the process of reaching extracting hydrocarbons is intensive. These oil sands contain large quantities of bitumen, which is a semi-solid, tar-like hydrocarbon that must undergo costly procedures in order to transform it into usable fuel. In the late 1990s, Canadian oil exploration efforts began to prove the existence of enormous reserves, much larger than originally projected. The figures estimated an increase from 5 billion to 180 billion barrels, placing Canada second to Saudi Arabia in terms of available reserves[11]. Oil companies began an ensuing speculative and investment frenzy in the Athabasca Oil

Before and After: Alberta's oil sands and bitumen extraction. Source: National Geographic, March 2009.

[11] Yergin, Daniel. "Unconventional. From Fringe to Mainstream: Canadian Oil Sands." *The Quest*. Penguin Press, New York. 2011. Pp. 252-259.

Sands in the remote Alberta tundra. Previous techniques geared towards oil production proved to be too expensive and unfeasible until the technologic breakthrough known as steam-assisted gravity drainage, or SAGD. This *in situ*, or on site, process relies on superheated natural gas and chemical components that heat the bitumen deep underground, where the resulting fluid is pumped to the surface. According to the Cambridge Energy Research Associates, SAGD has been described as the "single most important development of the twenty-first century" in terms of oil production technology[12].

The environmental footprint of this extraction process is considerable both above and below ground. Fort McMurray, located in the Wood Buffalo regional municipality, serves as the center of economic activity for these nearby fields. To date, the footprint of the oil sands reaches over 230 square miles. Mining operations require maintaining tailing ponds, which are full of a "yogurt-like toxic sludge," are a necessary byproduct of the process. These are regulated by the Wood Buffalo authority, but many concerns for local residents remain. Fort McMurray's "Frequently Asked Questions" site feature over 50% of questions directed at concerns of water color, taste, and quality[13].

Additionally, climate change concerns are growing, with scientific evidence pointing toward human activity as a significant contributor. Burning hydrocarbon fuels to extract electricity yields byproducts in the form of carbon dioxide, sulfur dioxide, nitrous oxide, particulate matter, and other emissions that are deemed harmful to the atmosphere and living beings. These greenhouse gas emissions (GHG) haven been proven to erode the ozone layer and increase the amount of solar radiation reaching the earth's surface. The fifth assessment report from the Intergovernmental Panel on Climate Change (IPCC) being released in 2014 indicates a 95% confidence level that human activity is attributed to warming patterns, and a "high confidence" that this will have devastating effects on the food supply,

[12] Ibid.
[13] Regional Municipality of Wood Buffalo. "Services and Utilities: Water, Frequently Asked Questions." http://www.woodbuffalo.ab.ca/living/Services-and-Utilities/Water.htm. Last accessed 14 March 2013.

increased destruction from severe weather, and potentially irreversible alteration to the earth's climate[14]. There is a clear understanding that localized drilling and mining have local, regional, and global implications that can affect human health abroad.

Third, hydrocarbons are becoming increasingly expensive and energy-intensive to extract. In the 1940s, the overall energy return on energy invested (EROEI) to extract a hydrocarbon output was lucrative, yielding about 100 to 1. When easily-extracted reserves are depleted, the search for new conventional oil leads to a diminished ratio of 25 to 1. *In situ* tar sands yield a 3 to 1 ratio. Once oil extraction declines below the crucial 1 to 1 EROEI point, then hydrocarbon extraction ceases to become a net energy source, though still retaining its commodity value. This point is referred to as the EROEI Cliff, where energy production can no longer sustain the needs of society[15]. It is difficult to determine exactly when this cliff will be reached, but it is a statistical certainty that is in the near future.

Despite political and scientific breakthroughs, it is evident that the easily accessible fuel is running short. Future reserves are locked deep under the oceans, frozen in desolate locations, or far from refinery centers that require intensive pipeline construction. The debate about the morality of oil extraction is very salient in the Keystone XL Pipeline, which plans to transport 830,000 barrels of oil daily over a distance of 1,700 miles from the Canadian oil sands to the Texas Gulf Coast[16]. Despite having not been built yet, it remains one of the most politically embroiled projects in current American energy policy. On one side of the debate, advocates for the pipeline promote the thousands of jobs that would be created through construction and increased economic activity from the refined oil. Additionally, advocates rely on the State Department's assessment that the pipeline would not "significantly

[14] Intergovernmental Panel on Climate Change. "Climate Change 2013: The Physical Science Basis." Full report available at https://www.ipcc.ch/report/ar5/wg1/. Last accessed 9 April 2014.
[15] Heinburg, Richard. *Snake Oil: How Fracking's False Promise of Plenty Imperils Our Future.* Post Carbon Institute. July 2013.
[16] Los Angeles Times Editorial Board. "Keystone XL, a Sorry Symbol of a Continued Reliance on Fossil Fuels." *The Los Angeles Times*. February 2014.

exacerbate" greenhouse gas emissions. Conversely, environmental groups against the pipeline cite the increased risk of spills, deforestation, and toxic runoff that could imperil both Canadian and United States territories.

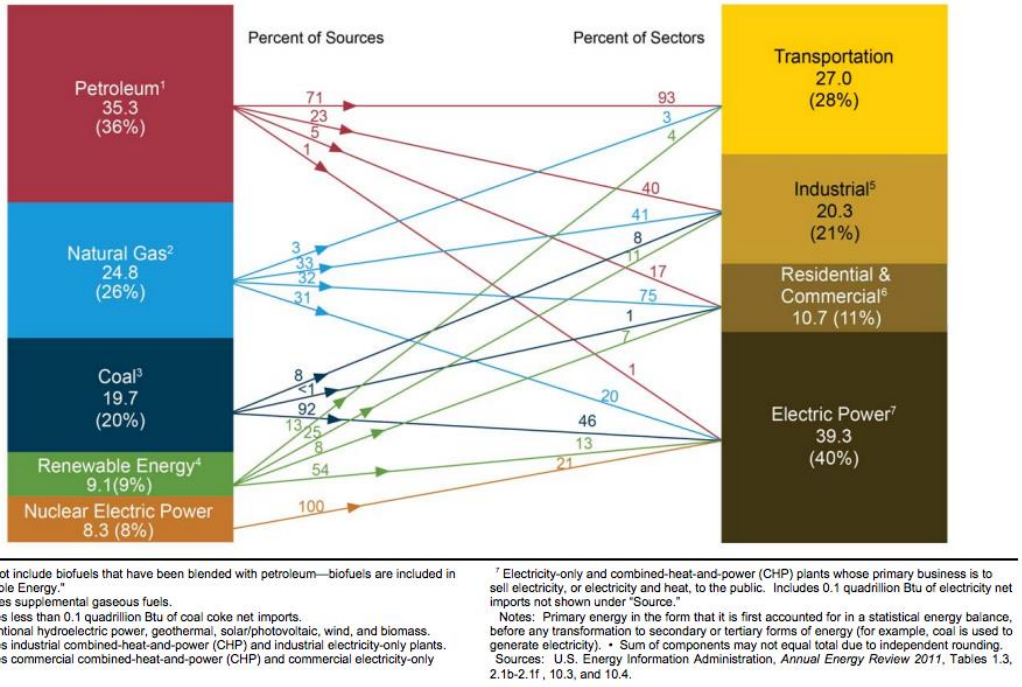
At the heart of this deliberation is the climate change debate. Research shows that oil from the Canadian oil sands emits 17% more carbon dioxide into the atmosphere than the average barrel of oil extracted from the United States because of the intensive practice of pumping super-heated water and chemicals into the ground to melt the bitumen[17]. This amounts to millions of tons of carbon pumped into the environment annually. On a symbolic level, the Keystone XL pipeline represents a battleground between relying on rapidly-depleting hydrocarbons and transitioning to alternative methods of energy production that are less taxing on the environment. Oil extraction is becoming undeniably more expensive and ecologically damaging to extract, and the direction of the nation's energy policy ought to be directed on environmentally-sustainable practices such as conservation and efficiency.

These three points highlight the fact that the Department of Energy's goal is necessary, yet very difficult to achieve. One approach that, in principle, seems widely accepted by society and politically valuable is focusing on energy efficiency. Energy efficiency can take different forms, such as conservation, productivity, and ingenuity. But the principle is generally the same: using less for the same or greater effect. This concept is amorphous, because efficiency does not flow through a pipe or carry through wired transmission. It does, however, have the potential to alleviate the soaring energy demand in the United States when applied wisely and effectively. It is attractive to consumers, who appreciate solutions to rising fuel prices. It is beneficial to energy producers because it reduces the strain on supply and can be controlled more freely. Energy efficiency is infiltrating into every sector of the economy, both in this nation and around the world. As cities expand and adapt to increasing

[17] Hargreaves, Steven. "Keystone's Hit to the Environment." *CNN Money*. November 2013.

populations and commercial activity, energy efficient urban design must rise to the forefront of consciousness for developers, planners, citizens and policymakers alike.

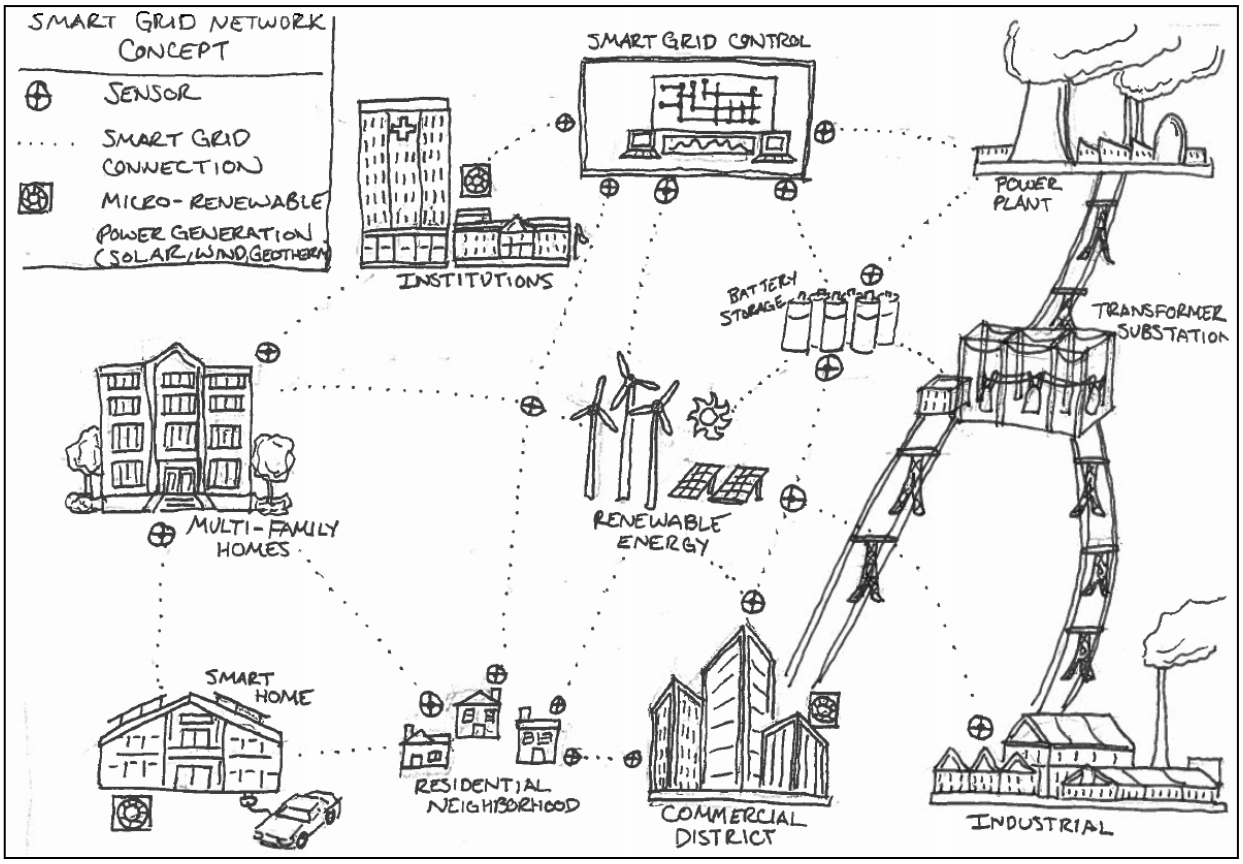
By examining energy consumption in the United States, the EIA has determined the main sectors where energy is used: transportation, industrial, residential and electrical generation[18]. Transportation consumes 28% of U.S. energy, which includes all vehicle usage of cars, freight trucks, and buses moving people and goods. Industry uses 21%, and includes manufacturing, processing facilities and factories that produce the consumer products and other components of the economy. Residential and commercial activities consume the least amount of energy of the four sectors, at 11%. These activities include all housing units, office space, and retail structures, and are the primary composition of a downtown urban core. The largest sector of energy consumption goes into electricity generation, at 40%. Here, the majority of fuel sources that provide the nation's electricity come from coal, nuclear, and natural gas.




Sources of Energy and Sector Usage. U.S. Energy Information Administration, 2011.

[18] U.S. Energy Information Administration. "Total Energy: Analysis & Projections." http://www.eia.gov/totalenergy/reports.cfm. Last accessed 5 December 2013.

Cities are a complex network of these four sectors, and each city varies greatly across the country. Civil engineering and urban planning initiatives are focused on modernizing the electrical infrastructure on both a micro and macroscopic level in order to improve efficiency, control electric delivery systems, and reduce fluctuations that result in instability. The "smart grid," as it is known, is a revolution in the electric grid that "combines time-based prices with the technologies that can be set by users to automatically control their use and self-production, lowering power costs and offering other benefits such as increased reliability to the system as a whole.[19]" There are three components to the smart grid: the network, hardware, and software. A sophisticated telecommunications network combines fiber and wireless linking the power generation plants, electrical transmission infrastructure, and the smart meter where energy is being consumed. Hardware installation includes all the meters,




Smart Grid Interaction Concept. Derived from *Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities*.

[19] Fox-Penner, Peter. "The New Paradigm: Enter the Smart Grid." *Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities*. Island Press, Washington, D.C. 2010. Pp. 34-45.

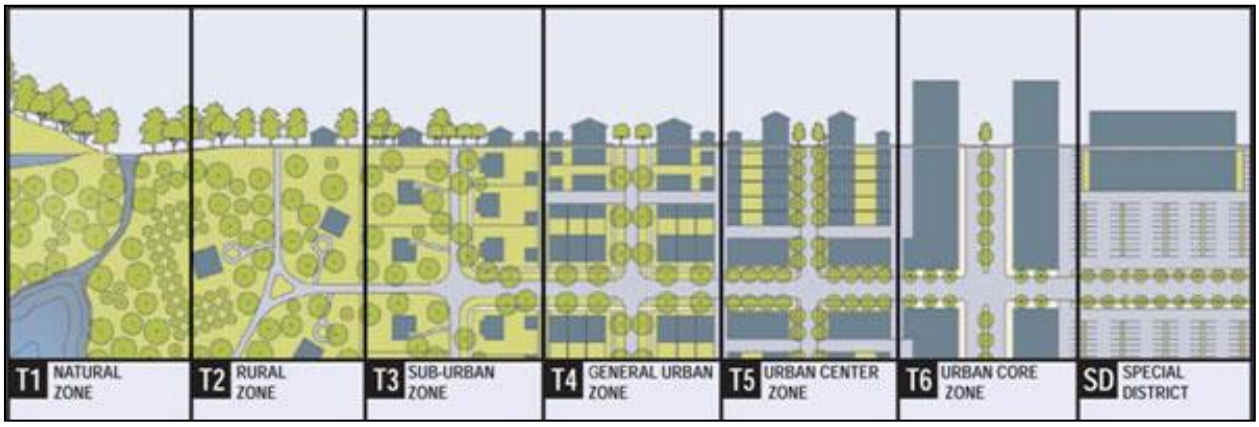
sensors, network gear, computers and data storage which facilitate streamlined integration of power delivery. Software developers map out the agency applications, databases, and management tools to ensure a streamlined process at every energy node. Together, these emerging technologies and cutting-edge innovations are forging the path for a smarter electric grid.

In 2009, President Obama declared the implementation of the smart grid a national priority. Speaking in front of the DeSoto Next Generation Solar Energy Center in Arcadia Florida, the president proclaimed: "It's time to make the same kind of investment in the way our energy travels—to build a clean energy superhighway that can take the renewable power . . . and deliver it directly to the American people in the most affordable and efficient way possible.[20]" Certain states and municipalities have taken the lead in installing new equipment, and both customers and energy providers alike have seen improvements. The EIA estimates that 9% of energy is lost due to an inefficient grid, which can be alleviated using best-practices and technology[21]. Smart grid integration is still far from becoming universal in the United States, due to the need for substantial capital investment, high up-front costs, and political opposition. Regardless, adopting the smart grid makes economic sense. It is gaining attention for its blending of technological, social and environmental benefits, and will soon become the future of the electric grid in America.

Smart growth is an emerging trend in urban planning which is a departure from the post-WWII patterns of development. This principle concentrates growth in compact, walkable urban centers in an effort to combat the negative effects of sprawl. Smart growth is the direction that many urban jurisdictions are taking, implementing local ordinances, regulations and funding priorities that best serve the economy, community, and the environment. Cities are identifying best practices to achieve this goal, including redeveloping underutilized areas, refurbishing brownfields into centers of mixed-use

[20] President Obama, Barack. "On Recovery Act Funding for Smart Grid Technology." Arcadia, FL. 27 October 2009.
[21] U.S. Energy Information Administration, "Annual Energy Outlook, 2013 with Projections to 2040." April 2013.

residential and commercial vitality, promoting affordable and equitable housing solutions, and developing transit-oriented development that reduces dependence on personal vehicles. As unwanted effects of urbanization such as traffic congestion, community disconnection, and urban decay become apparent, smart growth offers an organized, attractive alternative to bring people closer together in a sustainable manner.




Andres Duany, The Transect.

American architect and planner Andres Duany is credited for creating the smart growth transect model as an illustration for density, connectivity, and complete streets. The Transect is a framework for a sustainable rural-suburban-urban code which adopts a gradient of activity and urban form based on the Traditional Neighborhood District studies of Patrick Geddes. This Smart Code relates to lot size and density, but it also challenges planners to think of development regulation as part of city design by decreasing the necessity for automobile-centric transportation and improving alternative transit connectivity[22]. This framework could provide the means to a more sustainable urban form.

This study expounds on a three-part question: In our design of cities, how can we make them more energy efficient in response to depleting resources, rising cost of energy, and increasing demand for urban dwelling? How can we build and retrofit cities in a manner that integrates energy consumption

[22] Barnett, Johnathon. "Shaping Cities Through Development Regulation." *Redesigning Cities: Principles, Practice, and Implementation."* American Planning Association, Chicago, IL. 2003. Pp.264-267.

into public consciousness? And, can cities adopt the smart grid in conjunction with sustainable urban growth to become more resilient, equitable, and prosperous places? For the purposes of this study, energy consumption of residential, commercial and utility development is the primary focus.

The intent is to identify the areas where efficiency can be improved by means of articulating strategies of smart growth with smart grid technologies, employing desirable design techniques from the human perspective, and perennially enabling people to become an active component of their community. The synthesis of these three components is the definition of *attractive efficiency*. These principles can apply to individual buildings, but the focus is to examine the context of urban districts as an organic, complex unit. Some cities are adopting forward-thinking technology and design techniques, while others are not. Cities can be much more efficient than presently measured when employing these strategies. By redesigning existing urban areas with attractive efficiency, and controlling future development with an integrated process of the smart grid and smart growth, American cities can have a "starting place" to improve energy efficiency and become better suited for the challenges of the twenty-first century to foment equitable places for all.

**Transition to Attractive Efficiency**

Cities are not designed or redesigned by a single person, but rather they are the fruition of the labor of the citizen, public, and private sphere collaboration. The government—the public sphere—controls regulations that dictate street widths, setbacks, building codes, green space, or speed limits. Also, the government also invests tax revenue into special projects like streets, utilities, and public transit. Corporations and developers—representing the private sphere—invest in property in order to make a profit, manifested as sprawling shopping centers, office towers, neighborhoods, or condominiums. The citizen component is an interesting synthesis of spheres; they can be members of

both the public and private, consume the goods of the public and private, vote for public officials, and are subject to the laws determined by their policymakers.

Yet the key to bringing about change in an existing city or creating a new urban development is that it must be a reflection of the will of the citizens. People are the fundamental pillar of the three spheres, influencing—and being influenced by—the public and private spheres. The process begins with people; this is where the transition into a new conception of attractive efficiency must begin. How can such a drastic paradigm shift in urban planning take place? This question strikes both at the heart of planning theory and the American psyche. Because America was founded on vast expansion and possibility, transitioning into an efficiency consciousness is neither popular nor easy. But to scale back energy consumption, promote the proliferation of renewables, and wean off hydrocarbons, is both necessary and urgent.

The Japanese present an interesting social vignette that can be helpful to illustrate the change that is needed in the United States. Japanese culture is saturated with the virtue of *mottainai*: translating roughly in English as "too precious to waste.[23]" Japan has not enjoyed burgeoning expansion across a continent like the United States. Instead, the small island-nation, slightly smaller than California in terms of land mass, is geographically contained to operate and manage 127 million people strategically and efficiently. The infiltration of *mottainai* and energy efficiency is best illustrated in the Energy Conservation Law of 1979. This law ushered in the "Top Runner" program where the most efficient appliance or vehicle in the market becomes the standard. Within a given time frame, manufacturers must improve on the given level of efficiency in an ever-increasing quest for optimization. It is no wonder that Japan holds a global reputation in energy use in electronics, automobiles, and energy.

[23] Yergin, Daniel. "Closing the Conservation Gap. *Mottainai: '*Too Precious to waste.' " *The Quest*. Penguin Press, New York. 2011. Pp. 634-636.

Such change in the United States is certainly possible. Drastic changes in consumption have occurred through either strong leadership or crisis, but unfortunately, crisis tends to be the ruling impetus. During the oil crises of the 1970s, the federal government enacted a series of regulations to curb and control consumption, particularly with gasoline for passenger vehicles. In 1975, the United States enacted the Corporate Average Fuel Economy (CAFE) into the automobile industry. This has revolutionized the industry from producing cars with an average fuel economy of 18 miles per gallon (MPG) in 1978 to 30.2 MPG in 2011[24]. Though any effort to improve efficiency and control consumption is met with political opposition, such action may become universally accepted as energy supplies dwindle in the mid twenty-first century.

Many policymakers, planners, and stakeholders are opening up dialogues centered on the concept of the triple-bottom line to reach sustainability in planning efforts. The three tenets of this concept are finding an equilibrium balance among competing environmental, social equity, and economic interests[25]. The American tendency is to emphasize the economy as a means to enhance the quality of life for all; however, this approach usually benefits those who already have capital at their disposal. Environmental considerations are gaining attention as more regulatory solutions are applied to conserving the ecological systems of the natural world, upon which we all depend. The aspect of social equity, or what is good for all people, tends to be misunderstood, poorly diagnosed, or disregarded altogether. Ways of improving social equity into the sustainability model include providing affordable housing, community development, and community engagement into the design process. Only when these three tenets are equally balanced can a place reach a holistic sustainability model.

[24] National Highway Traffic Safety Administration (NHTSA). "CAFE: Fuel Economy." http://www.nhtsa.gov/fuel-economy. Last accessed 9 April 2014.
[25] USGBC. "Creating a Triple Bottom Line: Green Development + Social Purpose + Positive Returns." http://www.usgbc.org/articles/creating-triple-bottom-line-green-development-social-purpose-positive-returns. Last accessed 14 April 2014.

Urban design efficiency is catching on in America with the introduction of green building initiatives. In the 1980s, a number of private organizations identified the need to create a schema for evaluating the environmental impact of building from a comprehensive perspective in order to encourage energy conservation. The U.S. Green Building Council, founded in 1993, established the Leadership in Energy and Environmental Design (LEED) program in 1996 to create a nationally recognized standard to achieve this goal[26]. The LEED framework applies to both new and remodeled construction, laying out a specific rating scheme considering efficiency and environmental factors. Today, corporations compete to promote a green reputation by moving their operations into buildings rated as "certified," "silver," "gold," or the highly prestigious "platinum" rating.

LEED also incorporates neighborhood development (LEED-ND), which takes into consideration the context of the urban setting into the overall rating scheme. According to the USGBC, the LEED-ND rating system

> encourages smart growth and New Urbanist best practices by promoting the location and design of neighborhoods that reduce vehicle miles traveled (VMT) and creating developments where jobs and services are accessible by foot or public transit. It also promotes an array of green building and green infrastructure practices, particularly more efficient energy and water use—especially important in urban areas where infrastructure is often overtaxed.[27]

For instance, it is not sufficient to have a state-of-the-art, completely efficient research facility that is located 25 miles away from the urban core from where people commute. This results in large quantities of emissions from individual automobile traffic to and from the site. LEED-ND strives to create incentives for communities to create places where people live, work, and seek recreation in the same area. The result is a booming market in green development that is putting cities on a more sustainable path toward the future.

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[26] Yergin, Daniel. "Closing the Conservation Gap. Efficiency By Design." *The Quest*. Penguin Press, New York. 2011. Pp. 632-635.
[27] U.S. Green Building Counsel. "LEED for Neighborhood Development." http://www.usgbc.org/Docs/Archive/General/Docs6423.pdf. Last accessed 9 April 2014.

Until energy efficiency best practices are widely implemented across urbanized America, cities will continue to consume energy at an unsustainable level. It is the responsibility of planners, engineers, and policymakers to understand the magnitude of the future needs and the growing gap in conservation. Best practices in urban design have been successful at improving community connectivity, incorporating low-impact environmental solutions, and creating desirable places to live. With attractive efficiency holistically embedded in planning consciousness, cities can become even more resilient and equitable places for people, the economy, and the planet. Many cities are catching on to the importance of these initiatives, yet many more must learn from current best practices to become more resilient.

**Sustainable Cities: Case Studies on Boston, Austin, and Atlanta**

Much can be learned about sustainable initiatives in America's most energy efficient cities. By 2030, about 60% of the U.S. population will be classified as urban dwellers, indicating that city leadership must adopt practical solutions to meet energy needs in a manner that does not compromise their development priorities. The American Council for an Energy-Efficient Economy (ACEEE) is an organization dedicated to advancing energy efficiency policies, programs, technologies, investments, and behaviors to harness the city's full potential for energy efficiency[28]. The ACEEE recognizes that energy efficiency is potentially the cheapest, most abundant, and most under-utilized resource available for enhancing the economy in the twenty-first century. Cities are strategic for energy efficiency initiatives, in that they possess the necessary scale of interconnected labor markets, social networks, and interrelated economic activity that is conducive for large-scale policy adoption.

The ACEEE's City Energy Efficiency Scorecard ranks the top 34 metropolitan areas in terms of overall sustainability metrics such as overall consumption, established policy, and best practice

[28] American Council for an Energy-Efficient Economy (ACEEE). "About ACEEE: Overview & Mission." http://www.aceee.org/about. Last accessed 9 April 2014.

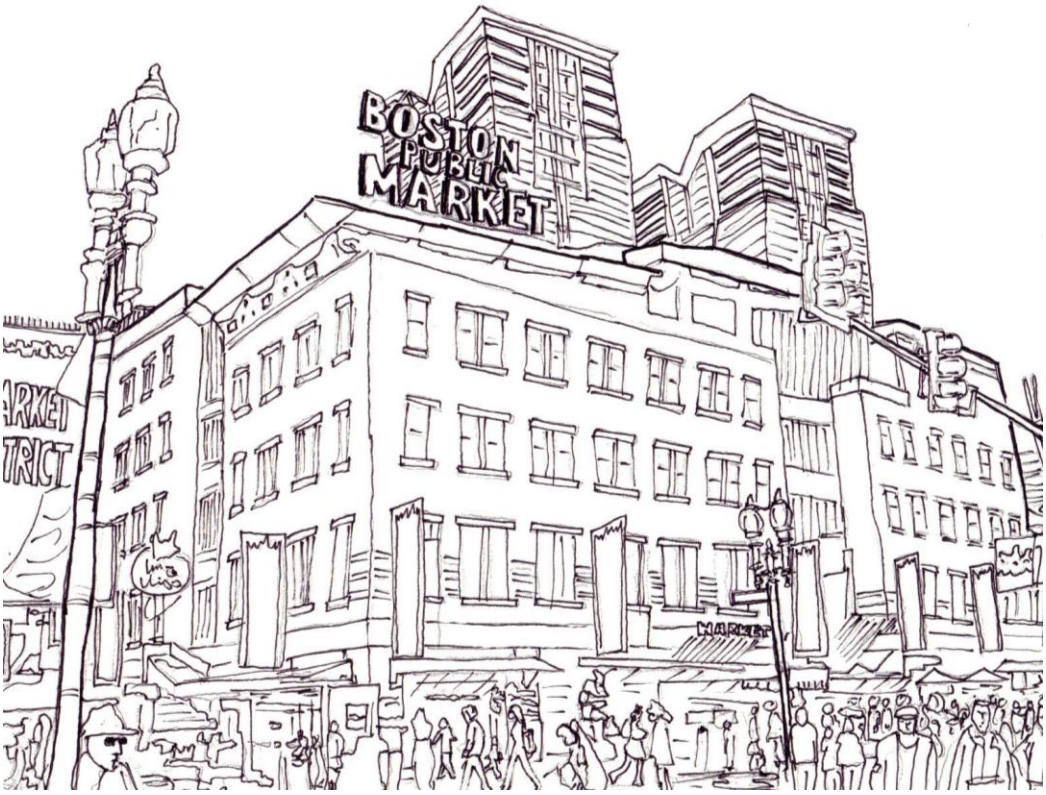
solutions. The intent of this scorecard is to enable other municipalities to identify areas where sustainability initiatives are attainable, as well as foster a spirit of competition to become the most sustainable city in the United States. Based on the report from the ACEEE, three cities stand out in terms of this initiative. The first case study features number one-ranking Boston, Massachusetts, because it is the national leader in efficiency and offers many valuable insights. Coming in sixth, Austin, Texas is the second city examined because it is a rapidly-developing leader in sustainable practices for the Southwest. Finally, ranking at number sixteen, Atlanta, Georgia will be reviewed as a metropolitan area that needs improvement, yet has an emerging framework for sustainability. Through the examination of these cities, this study will examine how attractive efficiency principles can assist in putting cities on a sustainable path for the twenty-first century.

Situated on the Western shore of the Massachusetts Bay, Boston is home to over 636,000 residents in an area of 48 square miles. It ranks as the 21st largest city in the United States, and is home to many successful corporations including Gillette, Liberty Mutual, and Barnes & Noble. Considered the leading front-runner for a municipal energy efficiency plan in the United States, Boston has become a desirable place for clean-tech industry while maintaining the safest streets for pedestrian usage. The city was the first in the nation to institute a metro-wide requirement for all large private construction projects to adhere to the USGBC's LEED standard[29]. Overall, Boston is a city with economic vibrancy, high quality of life, and environmentally sustainable practices.

The City of Boston's Department of Environment, Energy, & Open Spaces oversees all aspects of environmental policy, to include energy efficiency policy, green buildings, and renewable energy. The bedrock of the department's environmental policy is based on the Climate Action Plan, published in 2007. This plan acknowledges the effects of increased carbon dioxide levels in the atmosphere as a

[29] City of Boston's Environment, Energy, & Open Space Department. "Sustainability Accomplishments." http://www.cityofboston.gov/eeos/accomplishments/. Last accessed 9 April 2014.

significant contributor to global warming and rising sea levels. Because of its geographic location on the Atlantic Ocean, this is a matter that the city leadership takes seriously.




Sketch of Boston Public Market

The Climate Action Plan outlines a strategy to reduce GHGs 80% by 2050, while ensuring that policies aimed to improve environmental resiliency are equally distributed across all segments of society[30]. Transportation is an important component of the city's resiliency, employing vehicle efficiency standards that support electric vehicles, employing affordable and accessible public transit, and focusing on complete streets in an effort to reduce vehicle miles travelled. The plan addresses urban metabolism by creating a comprehensive framework for efficient solid waste management, mandatory recycling for residential areas, and reusing organic waste for compost at the neighborhood level. Additionally, the city incorporates community engagement into the policy decision making process by partnering with

[30] Green Boston. "A Climate of Progress: City of Boston Climate Action Plan Update 2011." April 2011. http://www.cityofboston.gov/images_documents/A%20Climate%20of%20Progress%20-%20CAP%20Update%202011_tcm3-25020.pdf. Last accessed 9 April 2014.

neighborhood-level organizations, creating a city-wide awareness campaign, and promoting climate education in schools[31]. These approaches have been effective at getting the people involved and informed in order to action on sustainability initiatives at the local level.

The key to Boston's success at establishing a reputation as the number one eco-friendly municipality in the United States is because of several reasons. First, the city government—from the mayor down to the public clerk—has made sustainability initiatives a priority through investment in green infrastructure, maintaining effective policy goals, and leading by example. Second, the people of Boston have bought into these initiatives, and continue to elect city leaders who represent their interests. Community groups enable people to be involved in the planning process, and they can see the direct benefits of their efforts. The important lesson learned is that with an informed citizenry, the people will support a government that is looking to enhance the three pillars of sustainability—economy, ecology, and equity.

Deep in the heart of Texas, Austin is a progressive city in a conservative state, but it is proving to be an innovative hub for energy efficiency programs that can transform the nation. Austin is the country's eleventh largest city with a population over 842,000, stretching over 272 square miles of Texas plains. Austin maintains a vibrant culture, known for its eccentricities, and hosts the nationally-acclaimed "South by Southwest" exhibition which features the latest developments in technology and culture. The city has been remarkably resilient in the midst of a global recession according to the Bureau of Labor Statistics: unemployment peaked at 7.5% at the height of the Great Recession, and

[31] Green Boston. "A Climate of Progress: City of Boston Climate Action Plan Update 2011." April 2011. http://www.cityofboston.gov/images_documents/A%20Climate%20of%20Progress%20-%20CAP%20Update%202011_tcm3-25020.pdf. Last accessed 9 April 2014.

preliminary data for the first quarter of FY'14 show it at 4.8%[32]. Much like Boston, Austin is proving that it is possible to balance the three pillars of sustainability.

Austin Energy is the city's publicly owned utility and municipal department that serves over 1 million residents in the metro area. 20.7% of their power generation capacity is in the form of renewables: wind, biomass, and solar, with a goal of 35% by 2020[33]. Austin Energy enforces the Energy Conservation Audit and Disclosure (ECAD) Ordinance, which requires homes and businesses to disclose energy consumption information in order to ensure compliance to existing regulations. Failure to comply with prescribed codes can result in fines to the individual or business. In addition, Austin offers a long list of rebates and incentives that reward compliance and efficient lifestyle practices, such as home composting, rainwater harvesting, and solar water heating. These monetary rewards can save consumers thousands of dollars annually[34]. Residents of Austin are generally supportive of these programs in order to achieve the city's goal of carbon footprint reduction.

Like Boston, Austin has a Climate Action Plan dedicated to reducing the carbon footprint of the city by lowering GHGs on a quantitative basis through five goals[35]. The first goal is to make all City of Austin facilities, fleets and operations completely carbon-neutral by 2020. This is done by emplacing solar photovoltaic on all municipal buildings and phasing in electric or alternative fuel-powered vehicles. Second, the city aims to make Austin Energy the leading utility in the nation for GHG reduction by enforcing an aggressive conservation campaign, achieving the 35% renewable energy goal by 2020, and by enforcing lowest-emission technologies for power generation. Third, Austin strives to implement the

[32] Bureau of Labor Statistics. "Local Area Unemployment Statistics: Austin-Round Rock- San Marcos, TX MSA." http://data.bls.gov/timeseries/LAUMT481242000000003?data_tool=XGtable. Last accessed 9 April 2014.
[33] Austin Energy. "Austin Energy At-A-Glance: Rated Generation Capacity." http://www.austinenergy.com/wps/portal/ae/About/At-A-Glance/austin-energy-at-a-glance/. Last accessed 9 April 2014.
[34] Austin Energy. "Power Saver Program." http://powersaver.austinenergy.com/wps/portal/psp/Home/. Last accessed 10 April 2014.
[35] City of Austin's Office of Sustainability. "Climate Protection Resolution No. 20070215-023, 2013 Update." http://www.austintexas.gov/department/austin-climate-protection-program. Last accessed 10 April 2014.

most energy efficient building codes in the nation for new and existing structures. This is done by phasing in the Zero Energy Capable Homes Initiative, which is a set of code improvements that reduce single-family home energy consumed by 31%, as well as other city-wide codes. Fourth, the Climate Action Team is enabled to identify where GHGs are concentrated, and work with stakeholders, technicians, and advisors to create comprehensive plans to lower these emissions. And finally, the fifth goal is to empower residents and visitors to reduce their carbon footprint using a public information campaign and by providing online tools to visualize ways to lower their energy consumption[36]. These strategies appear to be effective, as each year Austin is on track to reach its sustainability goals.

Austin residents have a high level of civic pride in their community, and they have many opportunities to pursue a green lifestyle. The City of Austin maintains a helpful reference guide for residents which outlines each efficiency program, including energy, water, renewables, commute reduction, and waste management[37]. Additionally, civic organizations strive to bring people together to take action and solve problems. Each week, there are farmer's markets, festivals, and other community programs designed to raise sustainable awareness. The City of Austin government establishes clear policy goals through the Climate Action Plan, and keeps citizens and businesses engaged through a set of incentives and penalties for compliance or non-compliance. These factors combined have proven to be attractive for businesses to come to Austin, and their current labor market projections are more competitive than the national average. Austin's example shows that sustainability policies can empower the people, grow the economy, and conserve the environment.

Atlanta is known by its moniker the "City in the Forest," and by its motto is *Resurgens*: "rising again." Both of these terms reveal the city's character, both as a sprawling metropolis with a vibrant

[36] City of Austin's Office of Sustainability. "Climate Protection Resolution No. 20070215-023, 2013 Update." http://www.austintexas.gov/department/austin-climate-protection-program. Last accessed 10 April 2014.
[37] City of Austin's Office of Sustainability. "Go Green Programs for Residents." http://austintexas.gov/sites/default/files/files/Sustainability/Residential_CityofAustin_GoGreen_Brochure_Inside_Rnd4.pdf. Last accessed 10 April 2014.

urban ecology, and as an emerging social and economic force rising up from the ashes of the Civil War. The city has about 443,000 residents over 132.4 square miles. Notably, Atlanta was the home of the 1996 Summer Olympic Games, which marked a significant improvement in its trajectory towards resilience and prosperity. CNN, Delta Airlines, and Turner Broadcasting System call Atlanta home, with many more businesses establishing home offices within the city limits. Atlanta ranks sixteenth out of 34 on the ACEEE city scorecard, which gives the city much room for environmental sustainability improvement.

The city's Office of Sustainability understands the magnitude of the environmental issues that will soon become burdensome to the metro area and the region. Since 2008, the City of Atlanta has partnered with the Georgia Institute of Technology to address ways to reduce the carbon footprint. As of 2014, the city has achieved half of its stated goals: a 12.5% GHG reduction, 23% fossil fuel reduction, 16% natural gas reduction, City Hall's 25% reduction in energy use, and 13% decrease in water usage at the Hartsfield-Jackson International Airport[38]. The Office acknowledges that much work has yet to be done to reach their goals of an 80% reduction of GHGs by 2050. The city is quantifiably decreasing its energy emissions, but some researchers question whether the pace is swift enough to reach this goal.

Through the Office of Sustainability's *Power to Change* program, the city has identified ten impact areas which can be influenced through a combination of policy, public awareness, and private investment. These areas include sustainability planning, air quality, energy efficiency & renewables, transportation, land use, materials management & recycling, water conservation, community health & vitality, growing business, and education[39]. Each impact area addresses five objectives in order to reach achieve success in each impact area. Mayor Kasim Reed has helped the department secure four federal and state grants worth $28 million dollars which will support 25 new projects around Atlanta.

[38] City of Atlanta's Office of Sustainability. "About the Office of Sustainability." http://www.atlantaga.gov/index.aspx?page=153. Last accessed 10 April 2014.
[39] Power to Change. "Sustainable Impact Areas." http://p2catl.com/impact-areas/. Last accessed 10 April 2014.

The most compelling plan that incorporates public and private collaboration is the Atlanta Better Buildings Challenge (BBC), established in 2011. This initiative challenges the city's Class-A office towers to make water and energy conservation strategies the bedrock of their operation management. As of July 2013, over 120 buildings spanning across Buckhead, Midtown, and Downtown have joined the pledge, amounting to 65 million square feet of floor area being monitored[40]. There is much momentum behind this program, because businesses understand that quantifiable efficiency improvements can have money and promote their branding in a favorable light. The BBC's goal is to transform commercial buildings by improving water and energy efficiency 20% by the year 2020 by increasing the sponsorship base, promoting community outreach and education, and by providing buildings with the tools they need to implement change[41]. As of 2013, 18 buildings have already achieved their target 20% goal, but much work has yet to be accomplished on a city-wide basis.

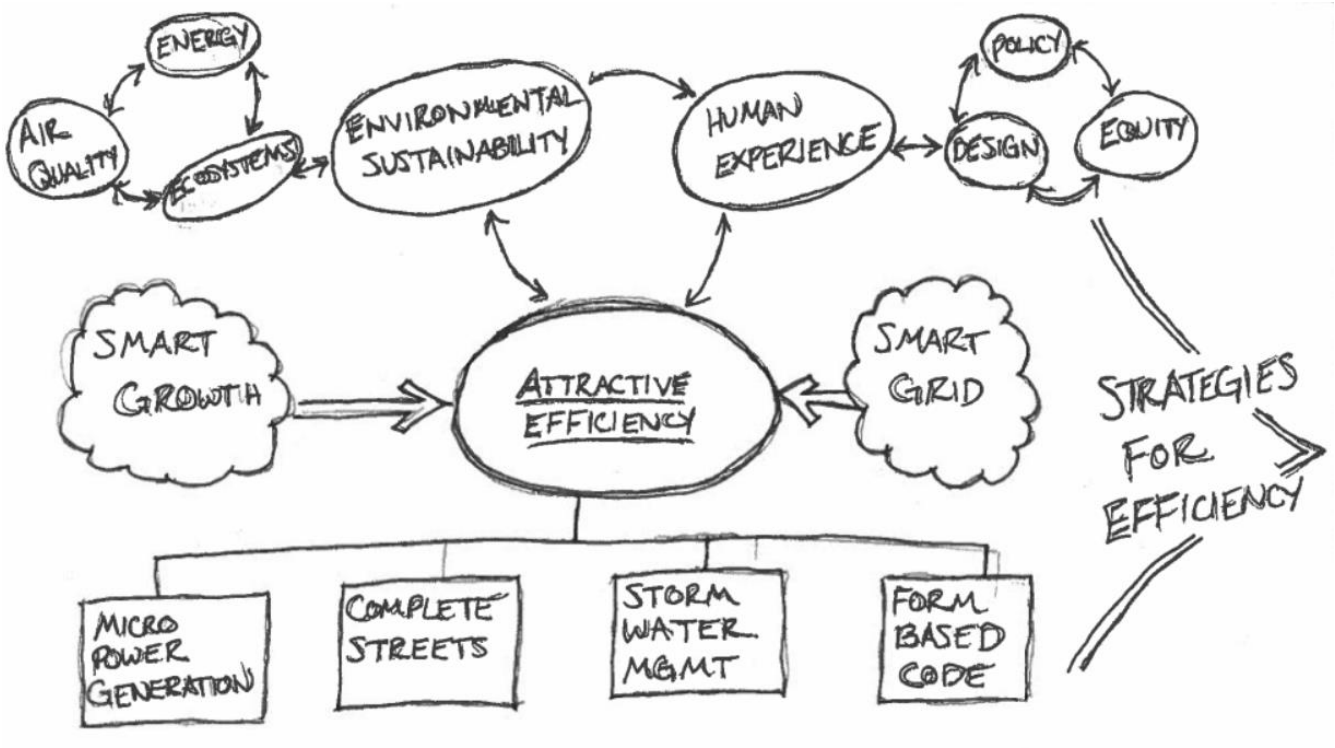
Compared to Boston and Austin, Atlanta's citywide sustainability department is relatively nascent and does not have as much wide-spread public backing. The structures of the three city's sustainability initiatives are all different, with varying levels of financial investment, social interest, and public backing. Successful city-wide sustainability efforts must be simultaneously top-down (being supported by the elected administration and staff) and bottom-up (having grassroots community engagement in support of these objectives). Boston is the most successful because the people and elected officials understand the urgency for action on climate change, as rising sea levels could be catastrophic for the city on Massachusetts Bay. Austin has developed a favorable reputation for green-tech and clean-tech industry because of its comprehensive sustainability incentive programs which reward compliance. Atlanta is increasing the pace of its sustainability efforts gradually in order to

[40] Torres, Anne. "Atlanta Better Buildings Challenge Recognizes Top Performers and Expands to Buckhead." Mayor's Office of Communications. 7 July 2013.
[41] Atlanta Better Building Challenge. "2013 Annual Report." http://atlantabbc.com/wp-content/uploads/2014/03/ABBC-2013-Annual-Report.pdf. Last accessed 16 February 2014.

become an eco-friendly hub for global commerce. By examining programs and progress at the city level, these can provide valuable insights for a comprehensive approach of urban energy efficiency.

**Strategies for Attractive Efficiency**

As this paper has discussed, there are a host of existing strategies to improve the energy efficiency of a new or existing urban setting. This is an emerging field, and there exists many more innovative ways to synthesize the emerging smart grid technology with the latest trends in urban smart growth. Attractive efficiency builds upon the existing conceptions of new urbanism and smart growth, but promotes these ideas on the merits of energy efficiency in an effort to add value and relevance to the dialogue of urban planning. This study identifies four areas where energy consumption can be reduced: micro-renewable power generation, street design, storm water management, and form-based code.




Attractive Efficiency Concept with Connections and Influences

These approaches are coupled with an emphasis on public information which connects energy consumption to the consumer in an effort to promote conservation. These efforts are framed with public policy tools available at the local, state and federal level to synthesize a comprehensive energy plan. Together, these efforts will bridge the gap and create a unified effort to promote conservation principles and make energy efficiency a universally accepted idea.

As an additional note, regional characteristics are a big component of attractive efficiency. Not all urban areas are created equally. For example, the charm of the Southwest is the origin of native cultures thriving in the arid and semi-arid climates of the desert. Adobe *pueblitos* first constructed by the Anasazi Indians used easily-accessible building materials with an understanding of passive cooling and heating techniques that maximize the dwelling's efficiency[42]. Today, many southwestern cities have adopted building standards that evoke this knowledge of working with the environment, rather than against it.

What works in the Southwest does not necessarily work in the American Southeast. Each region has its own strengths and weaknesses, and the intent is to amplify the benefits of a region's strength and provide solutions to bolster the region's weaknesses. Rather than providing a blanket framework for techniques and strategies, attractive efficiency outlines best practices and integrates regional considerations—altitude, climate, rainfall, wind speeds, or temperature—into an adaptable framework. The four aspects of micro-renewable power generation, street design, storm water management, and form-based code will each be examined to provide insights into effective energy consumption reduction strategies that urban settings in the United States can consider.

**Micro-Renewable Power Generation**

[42] Colorado Plateau Organization, Land Use History of North America. "The Anasazi or 'Ancient Pueblo.' " http://cpluhna.nau.edu/People/anasazi.htm. Last accessed 25 June 2013.

One of the key components to a thriving smart grid is the establishment of micro-renewable power generation (MRPG) sources using renewable energy that is built into the infrastructure of residences and commercial buildings. Their strategic importance is grounded in the fact that as the power grid fluctuates, these renewable sources can "fill the gap" in shortages in the electric power distribution network. The aspect of MRPG that is attractive to consumers is that depending on current demand levels, optimally performing MRPG can actually contribute back into the larger grid network, thereby reducing a consumer's energy demand or yielding a net surplus through feed-in tariffs[43]. Such renewable units can include solar panels, wind-generation attached to tall buildings in dense urban canyons where wind speeds are consistent, geothermal energy drawn from below the earth's surface, or micro-hydro-electric generation utilizing storm water runoff or natural tributaries. Each method of renewable energy comes at varying costs and feasibility due to regional climatic differences, availability of adequate technology, and cost restrictions. For the purposes of this study, solar and wind implementation will be covered due to their feasibility.

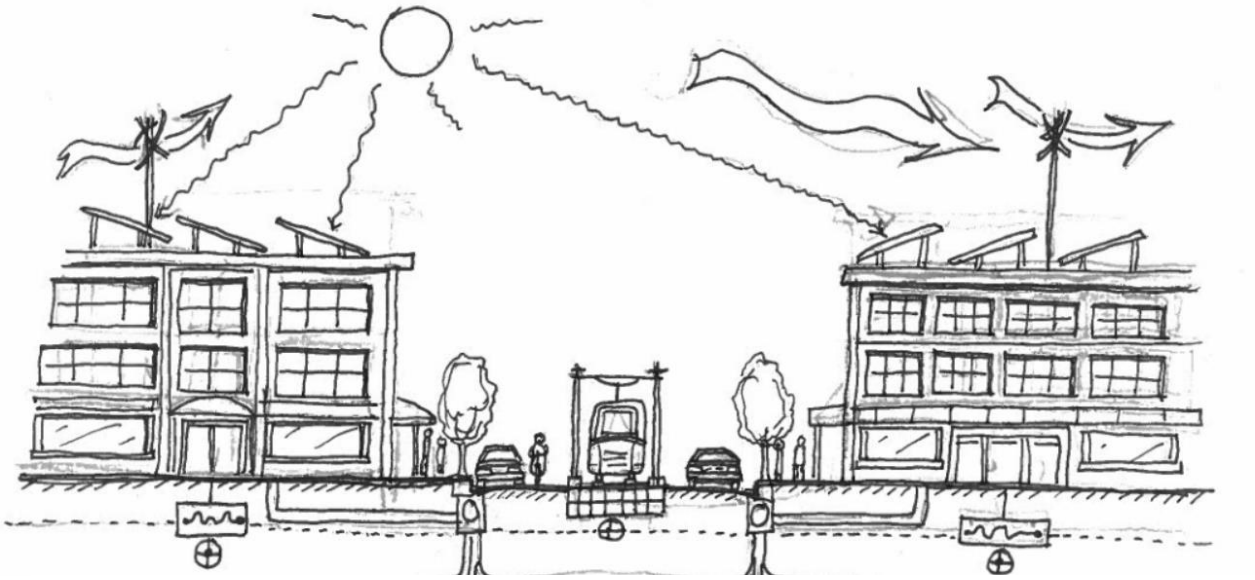
Modern technology presents more opportunities to determine how suitable a city or region is for employing various forms of micro-renewable power generation. For example, Geographic Information Systems (GIS) allows planners and engineers can create models of the total annual quantity of sunlight—both diffuse and direct—that reaches the surface of a building's rooftop. This modeling technique accounts for variations in altitude, latitude, atmospheric conditions, daily fluctuations of the sun angle, and shadow effects[44]. By running a simple solar analysis, the model can create an output that gives the total number of kilowatt hours per year of solar energy that a given location receives. From this data, engineers and architects can determine the most cost-effective strategy for emplacing solar

[43] Fierce Smart Grid. "ConEd Smart Grid Innovation Feeds Excess Power into the Grid." http://www.fiercesmartgrid.com/story/coned-smart-grid-innovation-feeds-excess-power-grid/2013-12-17. Last accessed 14 April 2014.

[44] Lopez, Anthony, Billy Roberts, et. al. "U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis." National Renewable Energy Laboratory. July 2012.

panels on rooftops. GIS can provide similar raw data for other forms of energy potential including wind and geothermal.

Solar panel implementation on rooftops is considered small-scale photovoltaic distribution generation (PV-DG). Typically, these panels generate around 10 kilowatts per hour (kWh); depending on the customer's demand, excess power can be assessed as a credit to the customer and excess energy can be stored or used elsewhere in the grid. Since the 1980s, these panels have become both more efficient and cheaper, with an improvement of 18% conversion efficiency, and a 60%-75% decrease in cost per kWh[45]. These costs can fluctuate depending on site-specific installation costs, as well as state and local tax credits. The feasibility of PV-DG depends directly on the government and utility incentives to make the technology more affordable for investors and consumers.



Solar, wind power and the smart grid network

[45] Fox-Penner, Peter. "The Great Power Shift: Photovoltaic Solar." *Smart Power: Climate Change, the Smart Grid, and the Future of Electric Utilities*. Island Press, Washington, D.C. 2010. Pp. 105-106.

As with solar photovoltaic, wind power's feasibility depends greatly upon the regional climatic characteristics use creates less than 25 kW output. According to the Department of Energy, areas with sustained winds of 8-12 miles per hour can sustain a micro wind generator with a reliable flow of electricity[46]. Installing a micro wind generator includes a wide array of additional components, including controllers, storage batteries, an inverter, wiring, and other rigging equipment to ensure stability. Wind does not maintain the same ratio of cost-benefit as solar, but technology continues to refine efficiency. By 2050, wind could become feasible enough to power individual buildings in a commercial district and reduce reliance of traditional grid power sources.

**Complete Streets**

Streets are more than a means for movement and accessibility; they serve a social and commercial dynamic as well. They are accessible to anyone (given there is no parade scheduled that day), fomenting connections between acquaintances and strangers alike[47]. It is where people receive their impression of a city—visitors can think of a city as clean, safe, noisy, boring, or dangerous based on their experience interacting with the intentional design of the street. If the city is an organism, then streets are the circulatory system that sustains it. Streets are the hallmark of the public sphere, connecting otherwise isolated private institutions to the people who depend upon them. Great streets integrate community, participation, diversity, and activity in a way that is comfortable and safe. For these reasons, it is vital that city leadership make street improvement and investment a significant portion of their operational budget.

With such large quantities of energy and social flow concentrated on streets, it is important to consider them as an opportunity for efficient design. Planners began to reconsider the street form that

[46] U.S. Department of Energy. "Small Wind Electric Systems." http://energy.gov/energysaver/articles/small-wind-electric-systems. Last accessed 15 April 2014.
[47] Jacobs, Allan B. "Introduction to Great Streets." *Great Streets*. Massachusetts Institute of Technology Press. 1993. Pp. 8-11.

was born out of the post-WWII patterns of urban development and sprawl that primarily served automobiles. Since the 1970s, cities have been legislating transportation policy that encompassed pedestrian, bicycle lanes, and public transportation options to give people more options to travel to and from their homes. The establishment of the Americans with Disabilities Act (ADA) in 1990 improved street access for people in wheelchairs, which greatly enhanced social equity. Complete streets focus on planned right-of-ways that ensure the safety for those travelling without cars.

This shift in transportation planning can greatly improve energy efficiency primarily by allowing people to commute without the reliance of vehicles. According to the National Household Travel Survey, 17% of trips are less than a mile, yet 47% of these trips are taken by car. 38% of respondents from the same sample of respondents reported that they are willing to walk to a school, work, or other institutions[48]. By increasing the number of commute choices, this can lead to significant energy reduction in the form of conserved fuel.

[48] U.S. Federal Highway Administration. "Summary of Travel Trends: 2009 National Household Travel Survey." 2009. Full report available at http://nhts.ornl.gov/2009/pub/stt.pdf.

Concept sketch of complete street at urban core

**Storm Water Management**

The practice of accounting for the flow of storm water runoff has dramatically changed since the 1970s. Historically, such efforts were focused on designing drainage systems using pipes, culverts, and streamlined channels that moved water quickly out of an area to prevent localized flooding. Over time, engineers began to better understand the impacts of surface runoff in terms of pollution carried by storm water that was degrading ecosystems and estuaries. The cost of remediating the aftermath of a flooded zone or to remove pollutants could be incredibly burdensome, with costs rising into the millions. Today, storm water management encompasses a complex and diverse range of considerations including stream baseflows, mitigation from flood damage, water quality, natural drainage functions, and

restoring the natural ecology[49]. The transition has shifted from centralized control measures such as large-scale underground culvert networks based on the rational planning method, towards more holistic and decentralized solutions such as on-site remediation and reuse of storm water.

Many localities have adopted storm water management ordinances in order to quickly address problems that immediately affect their area. Since the 2000s, engineers and planners have placed much emphasis on low-impact development (LID) ordinances, which are prescriptive requirements that accomplish a specified storm water objective. Maryland's Prince George's County is one such local authority that has effectively employed LID policy to control and utilize storm water. Components of the plan include:

- site planning: define the development footprint, reduce impermeable surfaces, increase drainage pathways
- hydrologic analysis: specify boundaries of watersheds, create hydrograph models of baseline flows, evaluate site planning benefits
- integrated management practices (IMPs): measures to control runoff based on evaluation of appropriate techniques
- erosion and sediment control: indicate how LID can attain compliance within this scope
- public outreach and education: inform residents, developers, stakeholders[50]

An effective storm water management program can reduce costs and dependence on energy intensive efforts as well. This is primarily accomplished through flood control. During periods of heavy rain, water naturally seeps into the ground where it is absorbed into the soil and water table. When the ground is compact and impervious, water will move laterally to collection points, rather than down into the surface. By focusing on groundwater recharge, this can ensure that surrounding areas will be less

[49] Randolf, John. "Stormwater Management and Stream Restoration." *Environmental Land Use Planning and Management*. Island Press, Washington, D.C. 2004. Pp. 434-473.
[50] Randolf, John. "Stormwater Management and Stream Restoration." *Environmental Land Use Planning and Management*. Island Press, Washington, D.C. 2004. Pp. 434-473.

susceptible to flooding[51]. LID techniques that can meet this requirement include implementing grass and vegetation swales, bioretention areas, and permeable paving.

Additional benefits from LID practices include environmental restoration and remediation. The table below illustrates each LID practice, and its capability of reducing a quantity of harmful substances. Infiltration is most useful to eliminate suspended solids in the water, as well as significantly reduce phosphorus, nitrogen, carbon, and metals to restore pH balance. Storm water wetlands are useful for reducing hydrocarbons and bacteria. Together, these LID techniques work naturally to restore the environment; man-made remediation techniques would cost thousands to achieve the same effect. As with any new conception of planning, there are additional costs to consider compared to a status-quo approach of planning. However, the long-term benefits of the strategies describes in this study can potentially offset any steep up-front costs over a period of time.

| Pollutant Removal Capabilities (%) of Stormwater Treatment Practices | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Practice | *n* | susp. solids | phosphorus | nitrogen | carbon | bacteria | HCs | Metals |
| Stormwater Ponds | 44 | 80 | 51 | 33 | 43 | 70 | 81 | 50-74 |
| Stormwater wetlands | 39 | 76 | 49 | 30 | 18 | 78 | 85 | 40-69 |
| Infiltration | 6 | 95 | 70 | 51 | 54 | N/A | N/A | 98-99 |
| Filters | 19 | 86 | 59 | 38 | 54 | 37 | 84 | 49-88 |
| Swales | 9 | 81 | 34 | 84 | 69 | (-25) | 62 | 42-71 |
| Ditches | 11 | 31 | (-16) | (-9) | 18 | 5 | N/A | 0-38 |

Source: Schuller (2000), Brown and Schuller (1997), Winer (2000)[52]

**Form-Based Code**

Urban typology can have direct impacts on the energy efficiency of the city. For example, arid regions of the country can employ building codes that shield pedestrians on the street or people in a building from direct sunlight, thereby keeping people cooler and reducing the need for additional air conditioning. Form-based code is a means of controlling the urban form and activities through

[51] Ibid.
[52] Ibid.

prescribed regulations in order to achieve a desired urban effect, either aesthetic or functional. Consider again Duany's transect model where a gradient of densities stretches from the rural to urban form. Form-based code articulates what is going on at each level of the transect, which has direct implications on human action. Such strategies commonly used in form-based code include setback controls, frontages, land use and zoning requirements, floor-area ratio and density regulations[53]. An optimal scheme of form-based code seamlessly integrates the boundary between the public and private space, enabling both separate spheres to work together, and gives the pedestrian a sense of place and wholeness.

Efficient form-based code can include many strategies to reduce the energy demand for an urban setting. One example is mandating green space for private and public spaces, which can reduce the heat island effect that can exasperate cooling needs during warm summer months. By increasing tree canopy, this improves the naturally-occurring function of the environment to provide cooling shade and transfer solar radiation into vegetation through photosynthesis. When trees and vegetation absorb water through the root system, water travels throughout the tree for cell growth, and the output product is converted into a gas. This gas is released through leaves in a process called evapotranspiration, which cools the air by using heat to evaporate the water emitted. Studies have shown that the degree of cooling from green space varies depending on geographic location. On average, peak air temperatures can be reduced by 5 degrees Celsius with vegetation compared to bare land[54]. Reducing heat island effect is a desired goal with attractive efficiency. Through green space improvements and streetscaping with trees, this can quantifiably reduce the demand for air conditioning of nearby offices and residences.

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[53] Dobbins, Michael. "Zoning: Provisions." *Urban Design and People.* John Wiley & Sons, Hoboken, NJ. 2009. Pp. 242-243

[54] U.S. Environmental Protection Agency. "Reducing Urban heat Islands: Compendium of Strategies." 2005. http://www.epa.gov/heatisland/resources/pdf/TreesandVegCompendium.pdf. Last accessed 14 April 2014.

Implementing setback requirements can improve air flow for ground temperature cooling, and sunlight access to buildings, which can reduce the need for interior lighting. This concept dates back to the late nineteenth century in New York City, where citizen began to voice concern that tall skyscrapers were blocking light and air flow from reaching the streets below. The city enacted the Zoning Resolution of 1916 to establish height and setback controls that balanced the residential and commercial activity of the district[55]. Since then, many cities have adopted similar frameworks both as a utilitarian function and as an aesthetic enhancement to improve the quality of the street. Setbacks can allow for more ground vegetation, street feature enhancements such as benches and bike racks, and improve pedestrian trafficability—all desirable outcomes as a part of the "complete streets" model.

Other prescribed controls of form-based code address parking availability, signage standards, and architectural cohesion which all affect the urban form outcome of a place. This regulatory framework is advantageous to people because they are accessible, flexible, and amendable. As a city's people and markets fluctuate, the form-based code requirements can adapt accordingly. Nearly all cities have public hearings on zoning regulations at the neighborhood, district, or city-wide level where issues and disagreements can be alleviated. People have a direct connection to the values of their property than outside developers, and may be properly motivated to make the best collective decisions to create the desirable urban form outcome. Such energy efficient form-based code implementations can be made possible if citizens find them a worth-while endeavor.

**Public Outreach and Information**

The central premise of attractive efficiency is the public information component. The connection point between sources of electricity and physical consumption is controlled by the consumer—or more accurately, the machine or device that serves the consumer's purpose. This

[55] City of New York Department of Planning. "History of Zoning and Background." http://www.nyc.gov/html/dcp/html/zone/zonehis.shtml. Last accessed 14 April 2014.

relationship between energy input and system output is so prolific in modern society that, generally speaking, people do not give it much thought. This is exactly where the opportunity to reduce energy consumption lies. According to microeconomic theory, one of the enablers that can support equitable markets is equal information distribution among all consumers. Yet information asymmetry—where one party knows more or better information than another in which to based transaction decisions—is one of the most common market failures in modern capitalism[56]. This leads to the principle of Pareto efficiency, where a decision cannot make one party better off without making one party worse off.

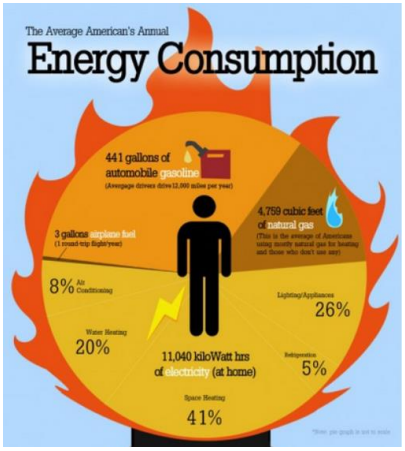
Private and public consumption of energy leads to different behavior. For example, an individual is generally well informed on the amount of fuel that he or she has in their personal vehicle. The fuel gauge explains in simple terms how much fuel in the tank is remaining, and how much has been consumed. Filling up gas at the pump is more transparent—there is a direct cost associated with the amount of fuel that is purchased. Armed with information and situational awareness, drivers are well-equipped to make travel decisions as a part of their daily routine.

In a public context, however, people are disconnected from the externalities and the actual costs of the energy they collectively consume. Apart from being taxpayers contributing to the public good, there is not a direct consciousness between the consumer and the illumination from a street light, the energy cost to upkeep maintenance on street trees, or the amount of electricity to power an escalator at a train station. These are all costs that are assumed by the public utilities, and has no bearing on the decision making process of an individual utilizing the good.

There is an emerging technology in the form of augmented reality (AR), which could provide the connection between the consumer and the utility. Augmented reality is a real-time or historical representation of one's surrounding environment that is supplemented with computer-generated

[56] Yandellis, Nicholas. *Economic Theory*. Springer-Verlang Publishers. Heidelberg, Germany. August 2013.

sensory input to convey information[57]. People can utilize AR with smartphone technology to gain information about the world in which they live and interact. On a simple level, a user of AR could hold up the smartphone to a grocery store to learn about the weekly specials. On a more complex level, a user could potentially scan the streetscape to learn about the energy consumption that is all around them. Such consumer-to-utility technology is a key aspect of the smart grid.



Sample Electronic Infographic delivered to smart phone or email. Source: Visual Economics

Attractive efficiency proposes using augmented reality to help inform people to use less energy. Users can register to have periodic consumption reports sent to their email in the form of the Efficiency Infographic Delivery System (EIDS). This service could allow people to track the energy used in their homes, offices, or on their daily commutes in order to connect the public conscience to energy consumption. This up-to-the-hour consumption report can bring in situational awareness about energy consumption patterns which are currently non-existent.

The citizenry is an underestimated force among public and private sector spheres. People can voice concern to their community leaders and elected officials to call for change when needed. Attractive efficiency offers people an opportunity to transform the way their commercial districts are designed, to transition away from unsightly overhead power line transmissions, shops with far setbacks, and large, dangerous parking lots. Mike Dobbins, professor of Urban Design Policy at the Georgia Institute of Technology, suggests that these changes "will not come at the initiative of the power companies or the governments that they so effectively lobby. Only citizen action informed and assisted by urban designers and developers for whom the benefits in quality are evident will determine whether

[57] Departmetn of Augmented Environments. "Argon2 Isotope." Georgia Institute of Technology. http://argon.gatech.edu/. Last accessed 13 November 2013.

such a goal is worth fighting for[58]." The framework outline in this study intends to enable people to reconsider the status quo of American urban development in order to make informed decisions about how their communities could look.

People can be skeptical of change. Skepticism can lead to resistance when there is a lack of information. However, the most appealing aspect of this proposal of attractive efficiency is that connecting consumers to the energy they use will lead to smarter decisions and consumption patterns. Using energy smarter and more efficiently at the consumer level results in cost savings of real money and on reduced environmental impact. If people were more informed about the energy implications of the choices they made, then society as a whole could make an impact at reducing per capita energy consumption.

**Attractive Efficiency and Human Health**

Human health in the urban setting is gaining attention as more Americans are moving to the cities. According to the Centers for Disease Control and Prevention (CDC) Healthy Communities Design Initiative, the physical design of a neighborhood or district can have direct effects on people's health, based on considerations such as access to sidewalks, green spaces, and clean air[59]. Attractive efficiency builds on Smart Growth strategies which diminish the prevalence of automobile-centric development which increases emissions, and promotes other transportation alternatives with a lower per capita emissions rating. Additionally, it enables people to use the urban setting as a safe and appealing place to run, bike, or walk. Attractive efficiency illustrates what a more efficient electrical transmission

[58] Dobbins, Michael. "Connections: Energy Generation and Transmission." *Urban Design and People*. John Wiley & Sons, Hoboken, NJ. 2009. Pp. 156-158.

[59] Centers for Disease Control and Prevention. "Planning and Health Resource Guide for Designing and Building Healthy Neighborhoods." December 2013. http://www.cdc.gov/healthyplaces/toolkit/default.htm. Last accessed 13 April 2014.

network could look like, thereby reducing the burden on power plants and yielding a reduction in consumption. These initiatives have beneficial second and third order effects, and can be correlated with an improvement in human health quality. Two areas where attractive efficiency can improve health are through reduced emissions and emphasis on the pedestrian, jogger or cyclist experience.

Emissions from vehicle tailpipes and point-source polluters such as power plants can pose a serious threat to human health. Not all emissions have the same effect, nor are all humans affected equally. Studies have shown that the young, infirm, or the elderly are at a higher risk in poor air quality conditions. Those living in cities with heavy traffic are more at risk than individuals living in rural areas. Scientists continue to research and analyze the effects of emissions on human health, but already there exist significant findings and correlations between specific emissions and health outcomes. Researchers estimate that the annual cost of hospital care due to emissions-related illness is approximately $193 million dollars[60]. The primary criteria pollutants that come from vehicles and power plants are particulate matter (PM 10, 2.5), carbon dioxide ($CO_2$), carbon monoxide (CO), nitrogen oxides (NOx), ozone ($O_3$), methane ($CH_4$), hydrocarbons (HC), and sulfur oxide (SOx). Each emission will be examined in turn with related health effects on humans.

PM is classified in terms of size: particulates measuring either 10 or 2.5 microns in length. Prolonged exposure to PM 2.5 is correlated with adverse health effects such as respiratory disease, cardiovascular disease, and lung cancer in people susceptible to poor air quality conditions. Similarly, PM 10 can cause damage to lung tissue, act as a carcinogen, or cause premature death. When high levels of PM are mixed with humidity and low temperatures in the right conditions, this can create

[60] Environment and Human Health, Inc. "The Harmful Effects of Vehicle Exhaust." http://www.ehhi.org/reports/exhaust/summary.shtml. Last accessed 16 April 2014.

poisonous fog, which can impact health and reduce visibility[61]. Today, such instances in the United States are rare, but have occurred prior to stringent air quality regulations.

$CO_2$ exposure can have deleterious effects on human health, depending on length and quantity of contact, age, health condition, and other characteristics of the person. By inhaling $CO_2$, the lungs displace oxygen intake, therefore resulting in blood toxicity. This can lead to asphyxiation, acidosis, and anoxia[62]. When oxygen is reduced between 10 to 13% with carbon displacement, humans are rendered unconscious and can die. Minor symptoms of $CO_2$ exposure include fatigue, light-headedness, dizziness, headaches, coughing, or fever. People with pre-existing health issues are more susceptible to the ill effects of $CO_2$ exposure.

CO emissions come predominately from mobile emissions, and are most concentrated in urban areas. Much like intense $CO_2$ exposure, CO can displace oxygen in the blood stream resulting in heart and brain failure in extreme cases. Even healthy people who are exercising or exerting themselves in the midst of high levels of CO can report health problems including chest pains, nausea, and dizziness. CO is particularly dangerous because it is odorless, colorless, and tasteless. Prolonged exposure in significant concentrations can transition from barely noticeable effects, to sickness, to death within a matter of hours[63].

NOx is highly toxic to both humans and animals. Lower concentrations can damage lung tissue, resulting in lung irritation, lung damage, or respiratory conditions similar to emphysema. People suffering from asthma are especially vulnerable to lung damage and respiratory disease. High levels of

[61] Kampa, Marilena. "Human Health Effects of Air Pollution." *Laboratory of Experimental Endocrinology*. June 2007. Full report available at http://www.sciencedirect.com/science/article/pii/S0269749107002849.
[62] Ibid.
[63] Kampa, Marilena. "Human Health Effects of Air Pollution." *Laboratory of Experimental Endocrinology*. June 2007. Full report available at http://www.sciencedirect.com/science/article/pii/S0269749107002849.

NOx can be fatal when the duration of exposure exceeds eight hours[64]. These emissions are also a key ingredient in smog, acid rain, and deteriorate water quality.

$O_3$ is a chemical compound naturally found in the stratosphere which protects the earth from the sun's radiation. When $O_3$ is concentrated in the troposphere near ground-level, humans and animals can suffer health consequences. $O_3$ can change the breathing pattern of the lungs and reduce the ability of the circulatory system to deliver oxygen to the body. $O_3$ is most damaging during warm seasons or in warm climates because the emissions are less diluted though the air, and undergo damaging chemical change when exposed to heat energy. Minor effects of ozone exposure include degradation of lung function, inflammation, coughing, chest pains, and cardiac complications[65]. Continuous exposure can lead to asthma, cardiac arrest, or death.

$CH_4$ is an odorless, colorless flammable gas that is a byproduct of energy combustion, decaying organic material, or through human and animal waste. Methane can be explosive at air concentrations as low as 5 percent[66]. When mixed with sulfides, it can take on a "rotten egg" odor, which is particularly dangerous to humans. Similar to aforementioned emissions, $CH_4$ can displace oxygen in the bloodstream, resulting in oxygen deprivation. Minor effects include shortness of breath, dizziness, and headache. $CH_4$ is rapidly expelled through the body via respiration, urine, or flatulence. The primary concern of $CH_4$ on human health is through extended exposure and lack of oxygen delivered to vital organs, or flammability when introduced to an ignition source.

HCs traces of unburned fuel that escapes into the atmosphere through exhaust or evaporating from a fuel tank. Cars, trucks, and buses can cause HCs to be emitted into the ambient air where humans can inhale the gases. Symptoms of HC inhalation include coughing, choking, or reduced lung

[64] Ibid.
[65] Ibid.
[66] Ibid.

capacity. Leukemia and liver cancer rates increase among people with prolonged exposure to HC. Other effects include dizziness, headaches, and loss of consciousness. HC can react with other compounds and create smog and acid rain[67].

SOx is formed when fuel containing sulfur is combusted, releasing the noxious compound into the atmosphere. When dissolved in water vapor, it can form acidic precipitation which can damage structures, humans, and animals alike. Coal-fired power plants are particularly responsible for emitting SOx into the surrounding environment. Catalytic converters installed on automobiles have greatly reduced the quantity of SOx from the atmosphere, but the harmful emission is still present in certain urban areas. Elderly and children are the most at risk, along with people who have heart or lung disease prior to exposure. Respiratory disorders are common with extended exposure of SOx over a period of years, and can also result in blood toxicity, nausea, shortness of breath, or chest pains. SOx can react with other compounds in the air to create smog, which greatly reduces visibility[68].

Attractive efficiency promotes healthy alternatives for people to walk and bike to their destinations, or enjoy jogging in a safe urban environment. Walking is a low-impact form of exercise which can maintain body weight, reduce the risk of type-II diabetes, and lower risk of osteoporosis. When biking in a safe environment, cyclists can improve their coordination and brain function while strengthening the immune system. Jogging has many health benefits as well, such as raising levels of good cholesterol and improving lung function. All of these activities can improve heart function by reduce blood pressure and decreasing the risk of sudden death from cardiac arrest. When an urban setting considers sidewalk improvements and bike lanes for the experience for non-vehicle commuters, this can lead to significant improvements in individual health.

[67] Kampa, Marilena. "Human Health Effects of Air Pollution." *Laboratory of Experimental Endocrinology*. June 2007. Full report available at http://www.sciencedirect.com/science/article/pii/S0269749107002849.
[68] Ibid.

As an improvement to the social component of sustainability, many planning organizations are incorporating health impact assessments (HIA) into their project or policy. The National Research Council defines HIA as

> a systematic process that uses an array of data sources and analytic methods, and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects within the population. HIA provides recommendations on monitoring and managing those effects[69].

Based upon the similar structure of the environmental impact assessment, the HIA seeks to assist communities in understanding the implications of a development and its effect on the quality of life for people. People living in their neighborhoods can greatly benefit by adopting the strategies outlined in attractive efficiency to improve overall quality of life.

**Sustainability for the Twenty-First Century and Beyond**

What is the value of a sustainable future for succeeding generations to have the same quality of life as we enjoy today? It is the responsibility of planners, policymakers and stakeholders to develop courses of action today that reflect the shared values of all people to determine the future course of history. Attractive efficiency, though not a solution in itself, offers a useful dialogue for those concerned about the future of American urbanism so that quality of life can apply to those living in the twenty-first century and beyond.

The physical environment in which an urban setting is located plays a perpetually critical role in its long-term sustainability. The environment provides the natural resources that the urban form needs, including raw materials, energy resources, and water. At ever-competing odds, the urban and physical worlds collide, often times with the environment losing the battle. The amount of environmental

[69] National Research Council. "Health Impact Assessment Defined." *Improving Health in the United States*. http://www.cdc.gov/healthyplaces/hia.htm. Last accessed 15 April 2014.

impact that a city has on the environment can be summarized with the ecological footprint, which is the measure of human demand of earth's ecological capital. This conflict is the center of a decades-old debate. How can an urban setting thrive without creating a lasting degeneration of the surrounding ecology? The answer for many planners and policymakers is to balance the three goals of sustainability—ecology, economy, and social equity.

Much can be learned from Boston's sustainability initiatives, America's number one energy efficient city.

The principles of attractive efficiency can address the needs of the environment, become a key sector of the economy, and balance increasing social demand for quality of life. A deeper knowledge of the surrounding natural and built environments in which we live will allow people to make powerful, informed decisions to enhance the quality of both.

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